Biomonitoring: Applications for Drinking Water Contaminants

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Presentation Goals

- Characterize the features and limitations of biomonitoring as an environmental public health tool
- Describe the use of biomonitoring to assess exposure in a population exposed to methyl-t-butyl ether (MtBE) in drinking water

Biomonitoring

- Assessment of human exposure to chemicals by measuring the chemicals or their metabolites in human specimens such as blood, urine, hair or nails
- Represents an increasingly available source of environmental public health data

How is Biomonitoring Useful?

- **Determine which chemicals are being absorbed and retained by humans**
- **Identify prevalence of people with levels above reference levels (Pb in blood)**
- **Establish reference ranges to identify what constitutes a significantly elevated level**

How is Biomonitoring Useful?

- **Assess effectiveness of efforts to reduce exposure to potentially harmful chemicals**
- **Determine distribution of exposure among at-risk populations (Hg among women of childbearing age)**
- **Identify trends in exposure over time**
- **Measure progress toward state and federal public health goals (HP 2010 and HW2010)**

Application to Drinking Water Contaminants

- Biomonitoring provides an *internalized* measure of exposure
  - For many contaminants, this provides a marker for exposure that logically would correlate better with actual exposure

Exposure to Drinking Water Contaminants

- Most commonly applied model:
  - Exposure (mg) = Sampled concentration (mg/L) X Daily water intake (L)
  - Based on two critical assumptions:
    - Concentration at tap varies directly with sampled concentration
    - Absorbed dose varies directly with tap concentration

Tap Concentration vs. Sampled Concentration

- Why might these not correlate?
  - Effect of household plumbing (Pb, Cu)
  - Blending and distribution within a public water system
  - Treatment systems:
    - Water softeners (radium)
    - Whole-house treatment systems (iron, arsenic)
    - Reverse osmosis (most everything)

Absorbed Dose vs. Tap Concentration

- Why might these not correlate?
  - Use of other water sources
  - Variability in how much water people drink
  - Genetic differences in absorption & retention
  - Dietary, occupational and other exposures
    - Lead in children
  - Inhalation of chemicals
    - Radon in air vs. radon in water
    - Use of hot water and ventilation
    - Exposure to gasoline

Biomonitoring and Health Risk

- When are biomonitoring data a useful marker of health risk?
  - Substances with long biological half-lives
    - Lead, arsenic and cadmium
  - Conditions where exposure is great enough to allow for biomonitoring to exceed lab limits
  - Situations where chronic exposure is the concern
    - Probably not useful for nitrate

Biomonitoring
Questions to Consider

- Can environmental exposure contribute to biological levels that can measured in the medium of interest?
- Do biological levels better relate to health risk than sampled water concentrations?
- Does its use supplement information from water sampling in a meaningful way?

Biomonitoring
Questions to Consider

- Does its use clarify who's at risk?
- Will people consent to sample extraction?
- Can the contribution of water-related exposure be quantified?

Human Exposure to Low Levels of MTBE in Drinking Water

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Overview

- **MTBE from Public Health Perspective**
- **NHANES & National Report on Human Exposure to Environmental Chemicals**
- **Health Effects Studies**
- **Pilot Study**

Public Health Impact: MtBE Exposure

- **EPA has identified 106 cities/counties in non-attainment with the Clean Air Act**
  - **11 cities/counties in non-attainment for CO levels**
- **USGS estimated 109 million Americans live in areas where MtBE is used**

NHANES

- **National Health and Nutrition Examination Survey**
  - **Conducted by NCHS, CDC**
- **Health and nutritional status**
- **Participants selected to represent the U.S. non-institutionalized, civilian population**

NHANES Subset 2000–2002: VOCs in Water and Blood

- **Subset of NHANES participants**
  - **Random selection of >1000 NHANES participants**
    - **1025 blood and 1256 water samples**
  - **Analysis of VOCs, including MtBE**

NHANES Subset 2000-2002: MtBE Results

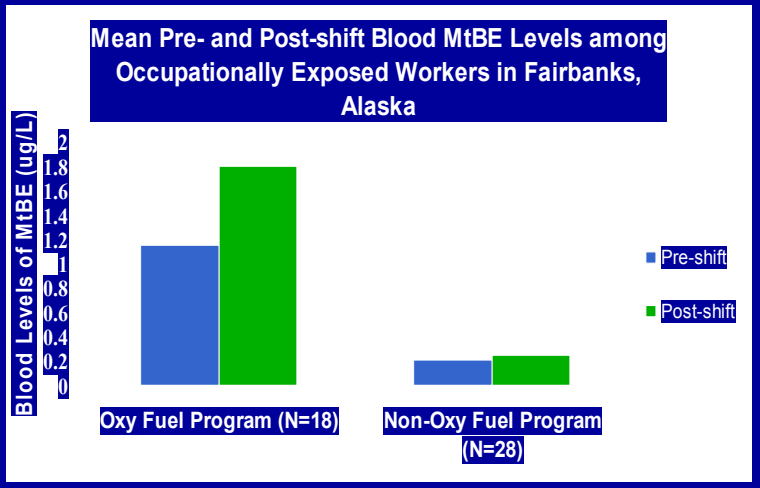
	Blood	Water
Geometric Mean	**74 PPTr**	**190 PPTr**
Median	**14 PPTr**	**80 PPTr**
Sample Size	**1025**	**1256**

MtBE and Health Effects

- **Acute health effects**
- **Chronic health effects**
- **Animal study**

Acute Health Effects

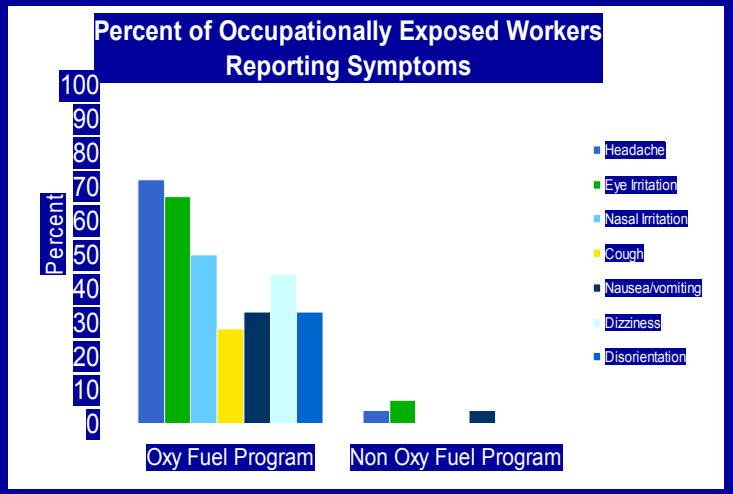
Study A



Source: Moolenaar et al., 1994. Archives of Environmental Health.

Acute Health Effects

Study A



Source: Moolenaar et al., 1994. Archives of Environmental Health.

Acute Health Effects

Study B

- Conducted in Stamford, Connecticut during oxygenated fuel program in 1993
  - Measured MtBE in personal breathing zone air, blood
  - Symptom questionnaire
- Results
  - MtBE levels in blood correlated with PBZ air
  - Symptom reporting associated with higher levels of MtBE in blood (2.4 ug/L)

Source: White et al., 1995. Archives of Environmental Health.

Chronic Health Effects

- 60 individuals exposed to 76 PPB to 14 PPB of MtBE & benzene in drinking water for several years
- Reported apoptosis in leukocytes in individuals exposed to MtBE and benzene in drinking water
- Limitation: Simultaneous exposure to benzene

Source: Vojdani et al., 1997. Human & Experimental Toxicology.

Animal Study

- Sprague-Dawley rat studies of MtBE
  - Doses: 1000; 250 ; & 0 mg/kg body weight
- Increase in leydig cell tumors in male rats
- Increase in lymphomas and leukemias in female rats

Source: Belpoggi et al., 1995. Toxicology & Industrial Health.

MtBE Exposure

What We Know

- **Potential widespread exposure from gasoline emissions and drinking water**
  - **Possible carcinogen**
  - **Possible apoptosis-inducer**

What's the Public Health Risk?

- **Verify extent of exposure**
- **Verify published results in a larger human study**

Objective of Pilot Study

To determine whether we could detect measurable levels in the blood of people exposed to low levels of MTBE in their drinking water

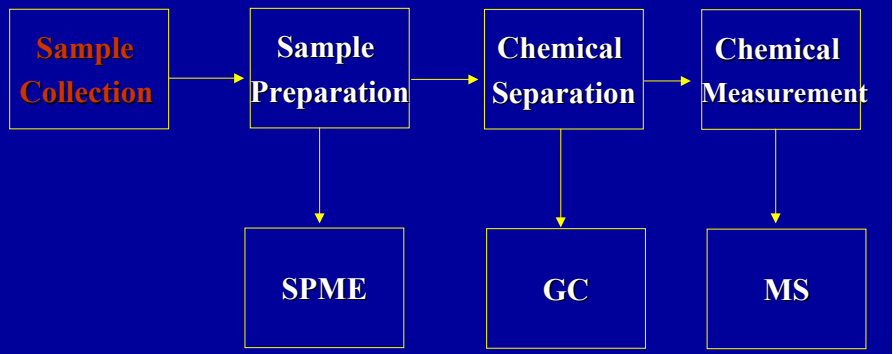
Pilot Study

- **Small community in Wisconsin**
- **Water contaminated with 1.2 - 5.0 ppb MtBE**
- **9 adult participants**
- **Collected blood and water samples**
  - **November 2002 (Well with no MtBE)**
  - **December 2002 (Well with MtBE)**

Study Inclusion Criteria

- Adults
- Drink at least two 8-oz glasses of tap water each day
- Could not pump gas or visit gasoline station 48 hours prior to blood draw
- Consent to blood draw and exposure questionnaire

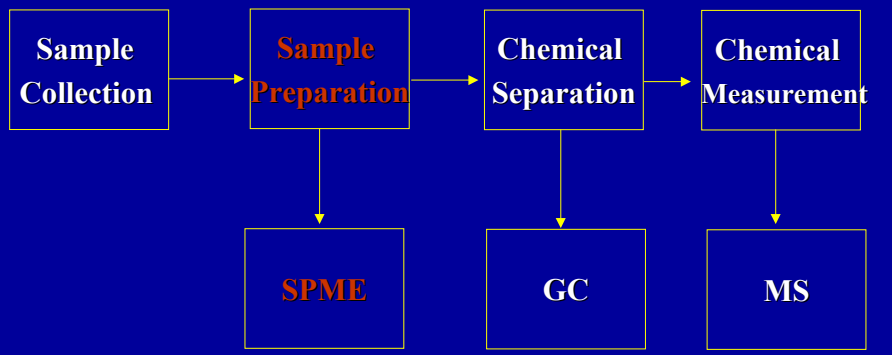
Methods



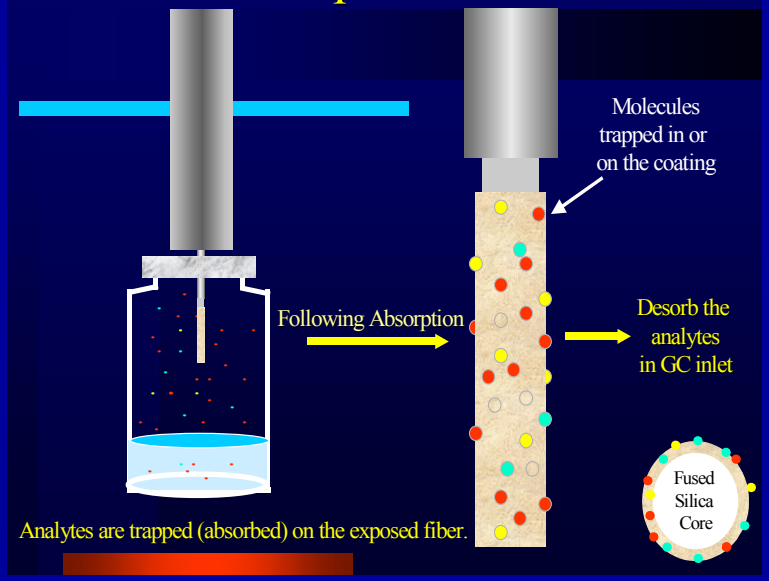
Sample Collection

- Blood Samples
  - Vacutainer® tubes prepared by CDC
  - Certified phlebotomist
  - 10-mL blood sample
  - Shipped overnight to CDC
- Water Samples
  - Non-aerated household faucets
  - 12-mL glass vials
  - Faucet ran for 3 minutes
  - Vial slightly overfilled
  - Shipped overnight to CDC

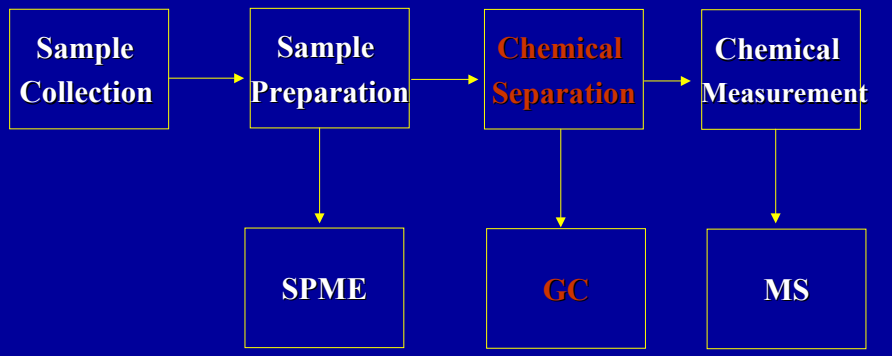
Methods



Headspace SPME

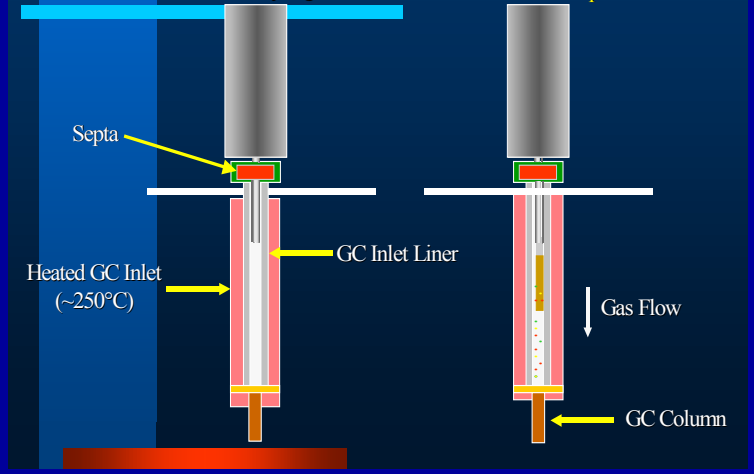


Methods



Desorbing the SPME Fiber

Analytes are baked off (desorbed) the SPME fiber and swept onto the GC column.



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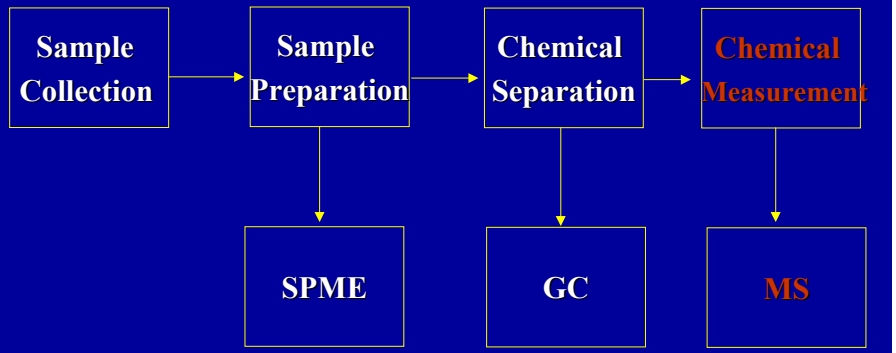
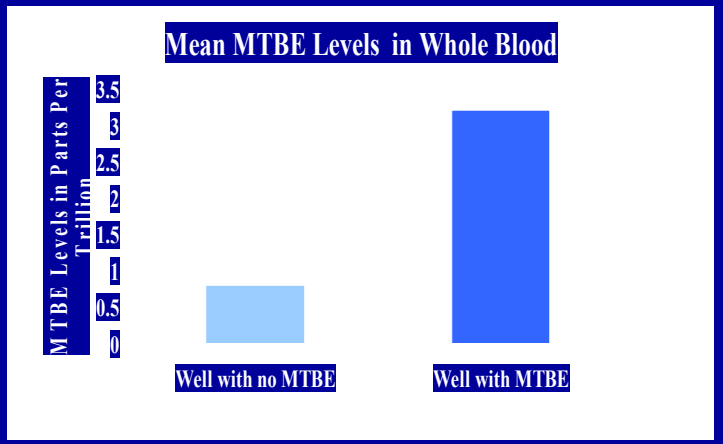


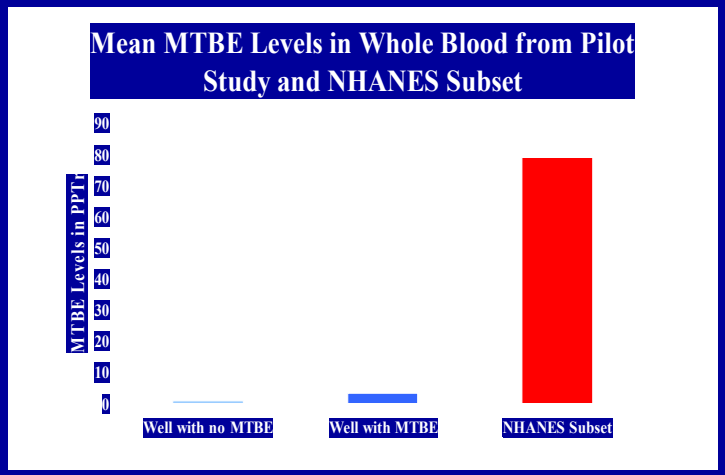
Results
Demographics

- **Average Age = 43 years**
- **All White, Non-Hispanic**
- **4 Females and 2 Males**

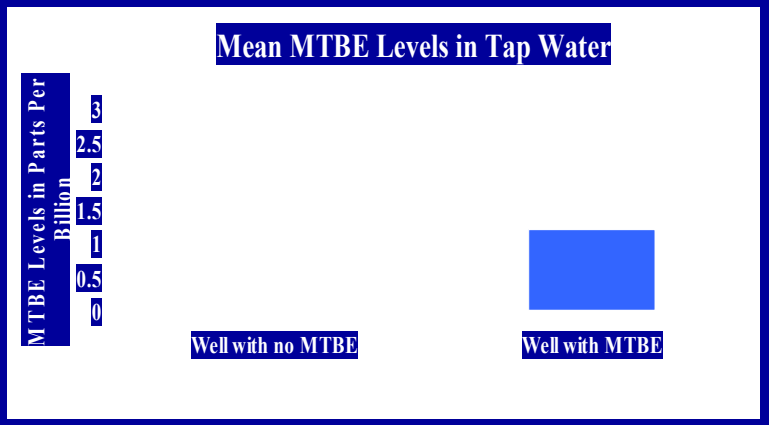
Results
Blood



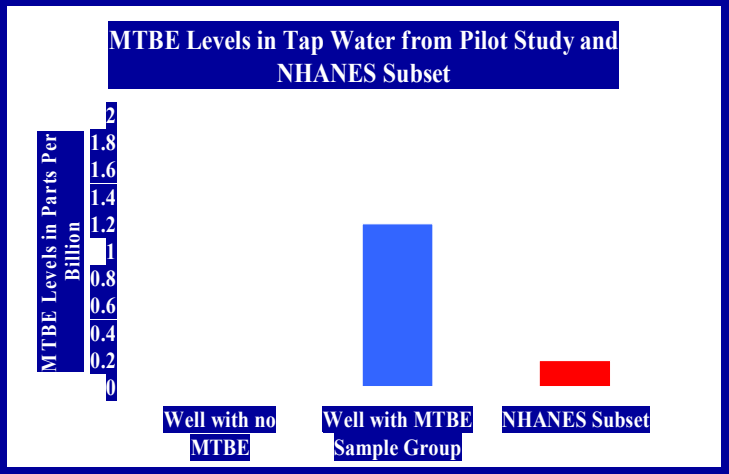
Results
Blood



Results
Water

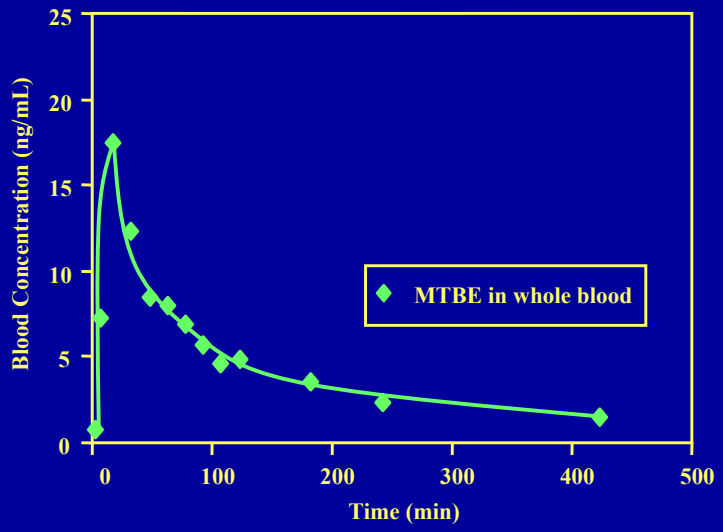


Results
Water



Discussion

- **MTBE metabolism**
  - **Oral exposure**
- **Sample population**
  - **Sample size**
  - **Minimal commuting**



Conclusions

- **Very low levels of MTBE were detected in the blood of people exposed to tap water contaminated with very low levels of MTBE**
- **Blood levels of MTBE can be used as a biological marker of exposure in drinking water**

Next Steps for MTBE

- **Conduct epidemiologic study of health effects from exposure to MTBE**
- **Assess how different exposure routes impact internal dose and health effects**

Acknowledgements

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